Advanced Characterization and Monitoring of Chemical Transport in the Vadose Zone at Hanford

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Outline

- Types of probes used to collect pore solution
- Limitations of suction lysimeters
- Innovative Field Methods and Instrumentation
  - Suction lysimeters with minimal headspace
  - Water- and concentration-flux meters
  - Radon/Thoron ratio in soil gas
- Uncertainties of measurements using “point”-type probes
    - 3D numerical modeling in spatially heterogeneous soils
    - Box Canyon and Large Scale Infiltration Tests at INEEL

Suction Sampler Summary (ASTM D 4696-92)

Sampler Type	Porous Section Material	Maximum Pore Size (µm)	Air Entry Value (cbar)	Operational Suction Range (cbar)	Depth (m)
Vacuum lysimeters	Ceramic PTFE Stainless steel	1.2 to 3.0 15 to 30 NA	>100 10 to 21 49 to 5	<60 to 80 <10 to 21 49 to 5	<7.5 <7.5 <7.5
Pressure-vacuum lysimeters	Ceramic PTFE	1.2 to 3.0 15 to 30	>100 10 to 21	<60 to 80 <10 to 21	<15 <15
High pressure-vacuum lysimeters	Ceramic PTFE	1.2 to 3.0 15 to 30	>100 10 to 21	<60 to 80 <10 to 21	<91 <91
Filter tip samplers	Polyethylene Ceramic Stainless steel	NA 2 to 3 NA	NA >100 NA	NA <60 to 80 NA	None <7.5 None
Cellulose-acetate hollow-fiber samplers	Cellulose Acetate Non cellulosic Polymer	<2.8 <2.8	>100 >100	<60 to 80 <60 to 80	<7.5 <7.5
Membrane filter samplers	Cellulose Acetate PTFE	<2.8 2 to 5	>100 NA	<60 to 80 NA	<7.5 <7.5

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Limitations of Suction Lysimeters

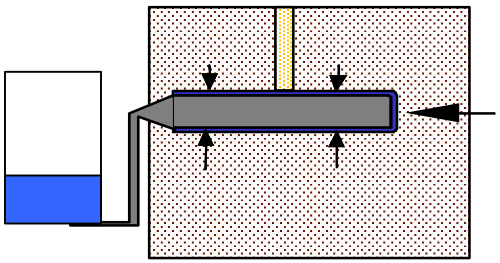
- Pore solution samples under vacuum can be taken only from relatively wet soils
- Evaporation of volatile chemicals in the lysi-meter headspace can reduce their concentration in a liquid phase
- The porous membrane can adsorb chemicals and colloids
- Concentration measurements depend on the vacuum applied in a heterogeneous formation

Other Methods

- Electrical Conductivity
- Electromagnetic induction
- Fiber Optics
- TDR Probes
- Pore Water Extraction by Refractometer
- Seamist Absorbent Pads

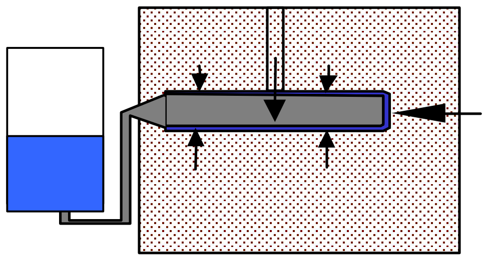
Effect of vacuum on concentration measurements using suction lysimeters

Dry soils/rocks



Concentration in Matrix

Wet soils/rocks



Concentration in Fracture

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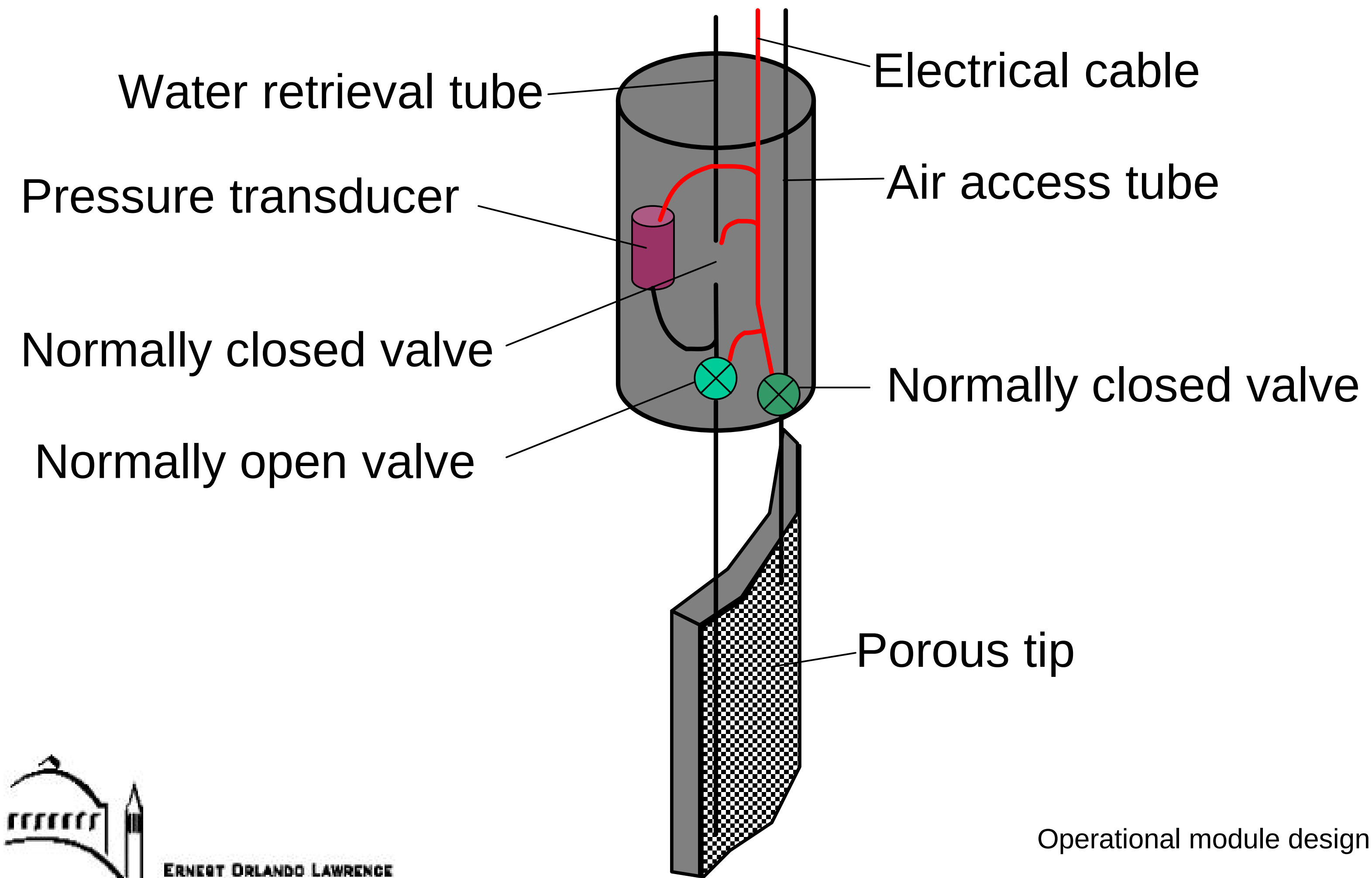
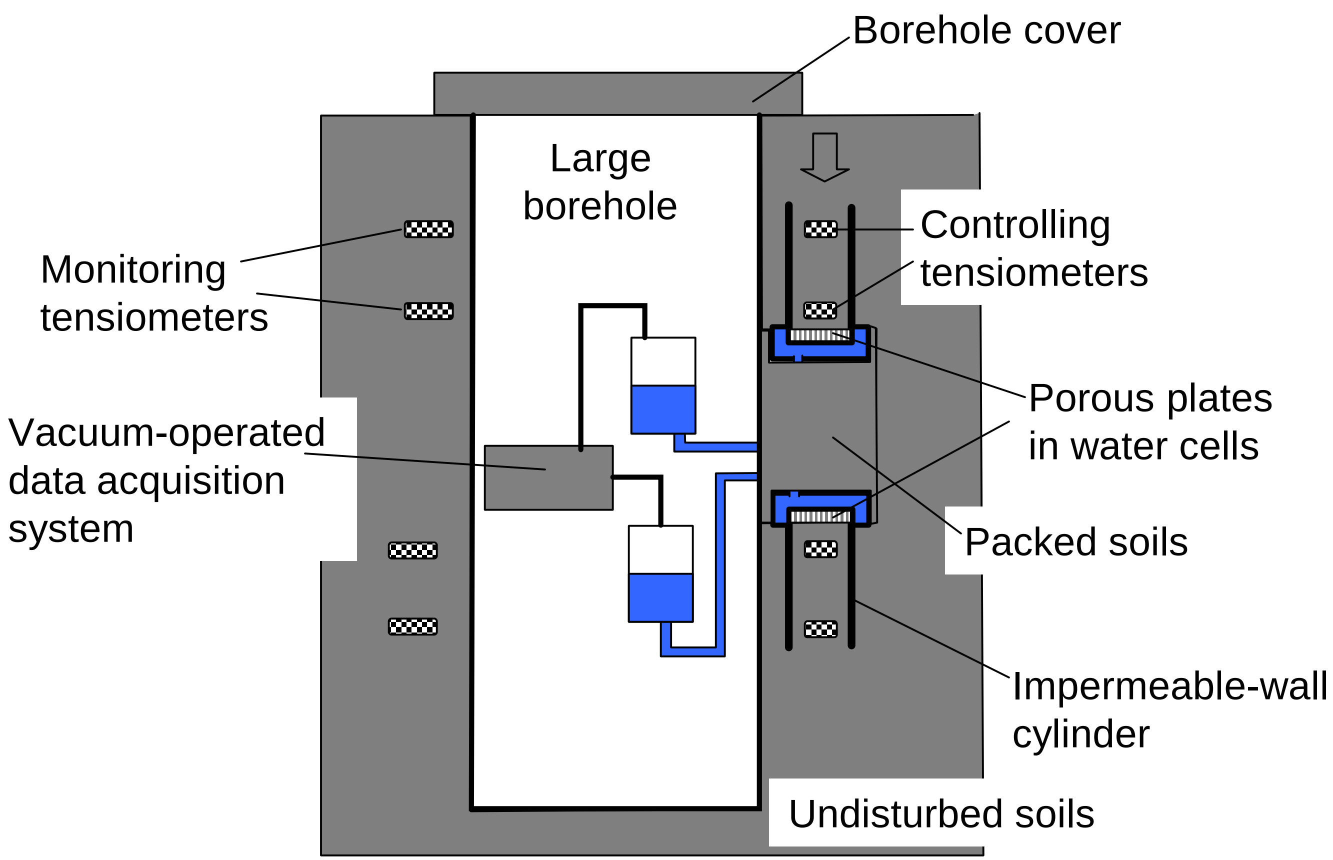
Schematic of advanced suction lysimeter - reduces lysimeter's head-space and has a curved porous element



Operational module design by B. Freifeld

Schematic of a vadose zone water- and concentration fluxmeter

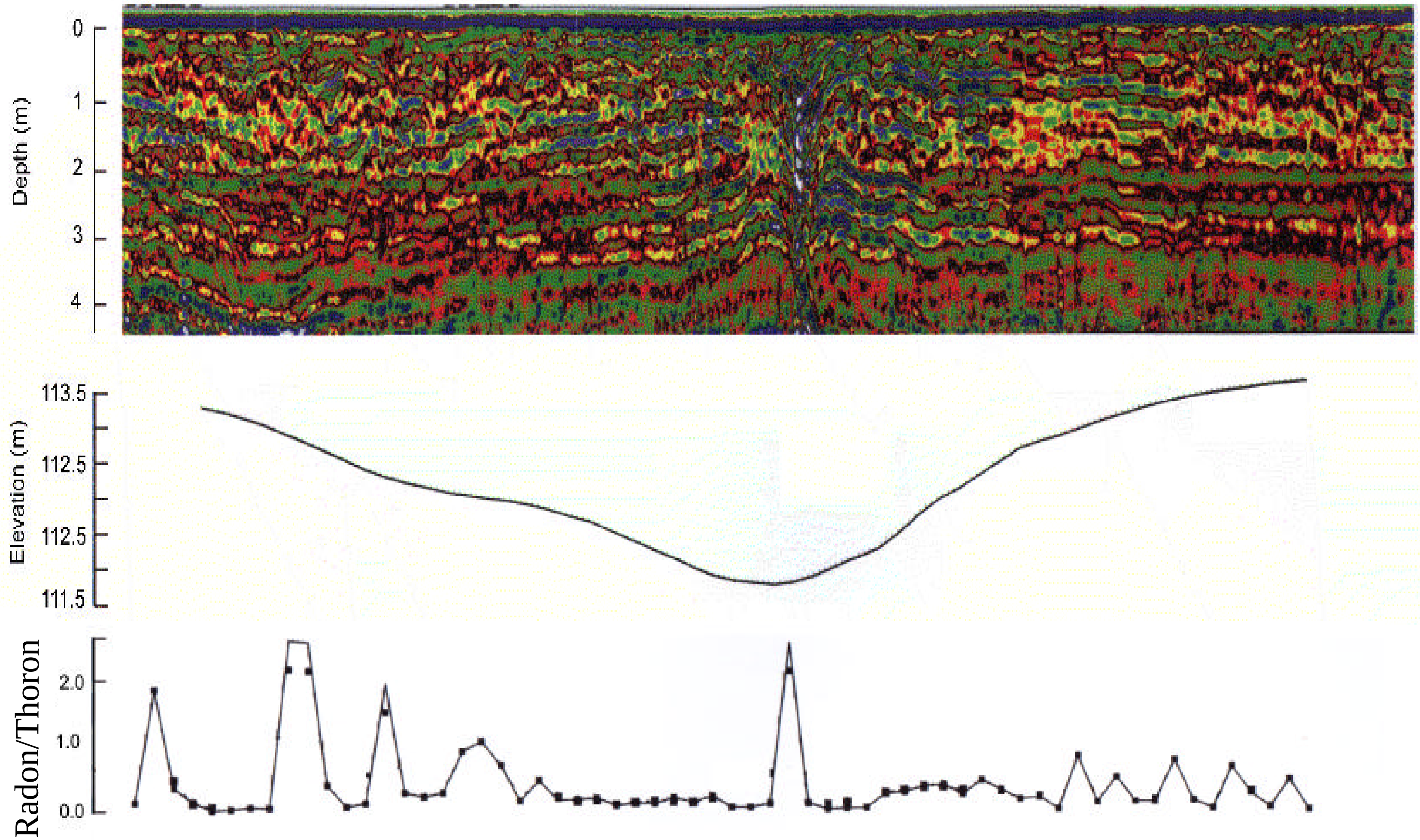


Porous plate surface-averaged water flux and concentration measurements under natural hydraulic gradient

Soil- Gas Sampling for Radon

- Radon-222 concentration in soil gas depends on (Hutter, 1996):
  - porosity, barometric pressure, precipitation, temperature, soil permeability, moisture content, and temperature
- The ratio of ^{220}Rn (thoron) to ^{222}Rn can be used to assess the near surface weak zones, such as clastic dikes.

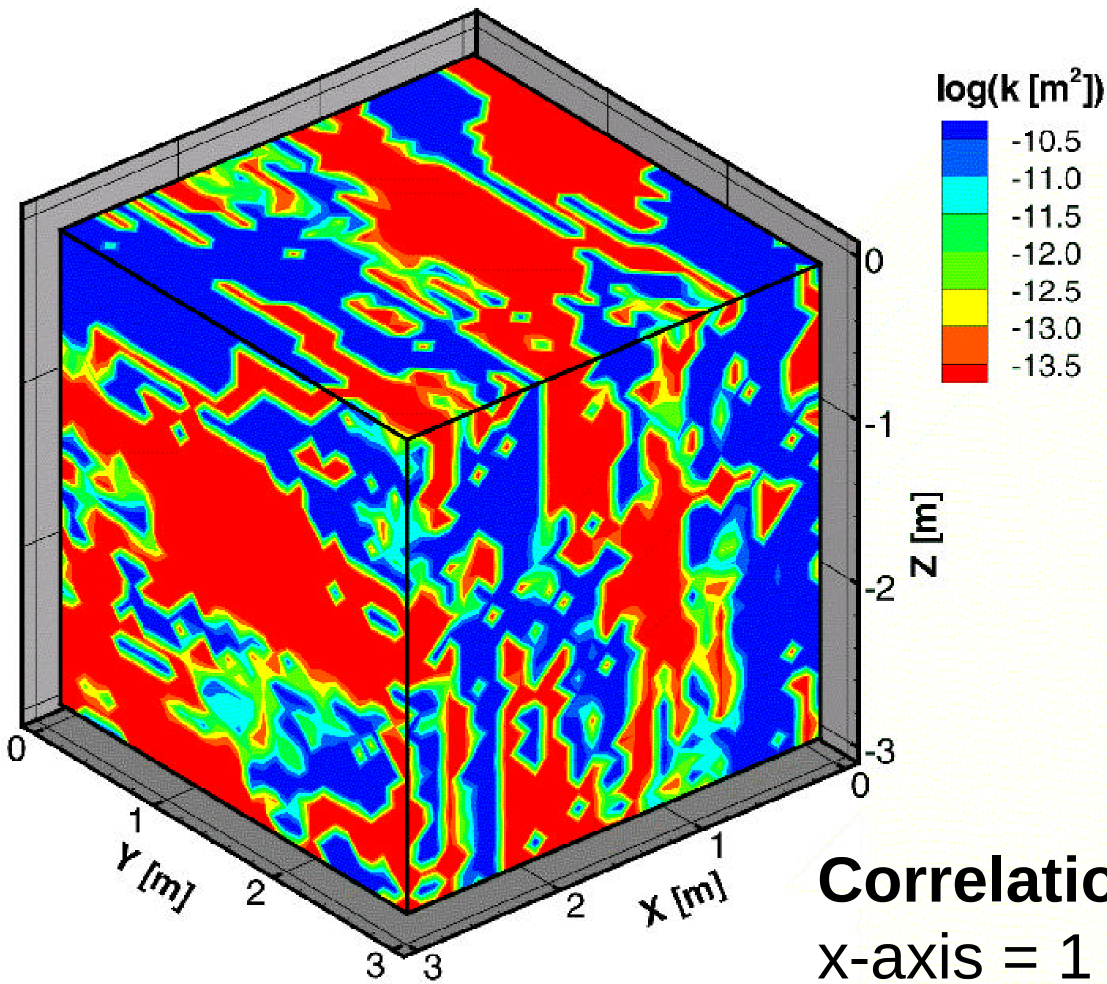
Comparison of surface radar and Radon/Thoron methods to determine zones of preferential flow (Chernobyl site data)



Shestopalov et al., 2000

- Spatial variability of soil hydraulic properties creates significant spatial variability of water arrival time and concentration

3-D Permeability Distribution



Correlation scales:

x-axis = 1 m

y-axis = 3 m

z-axis = 5 m

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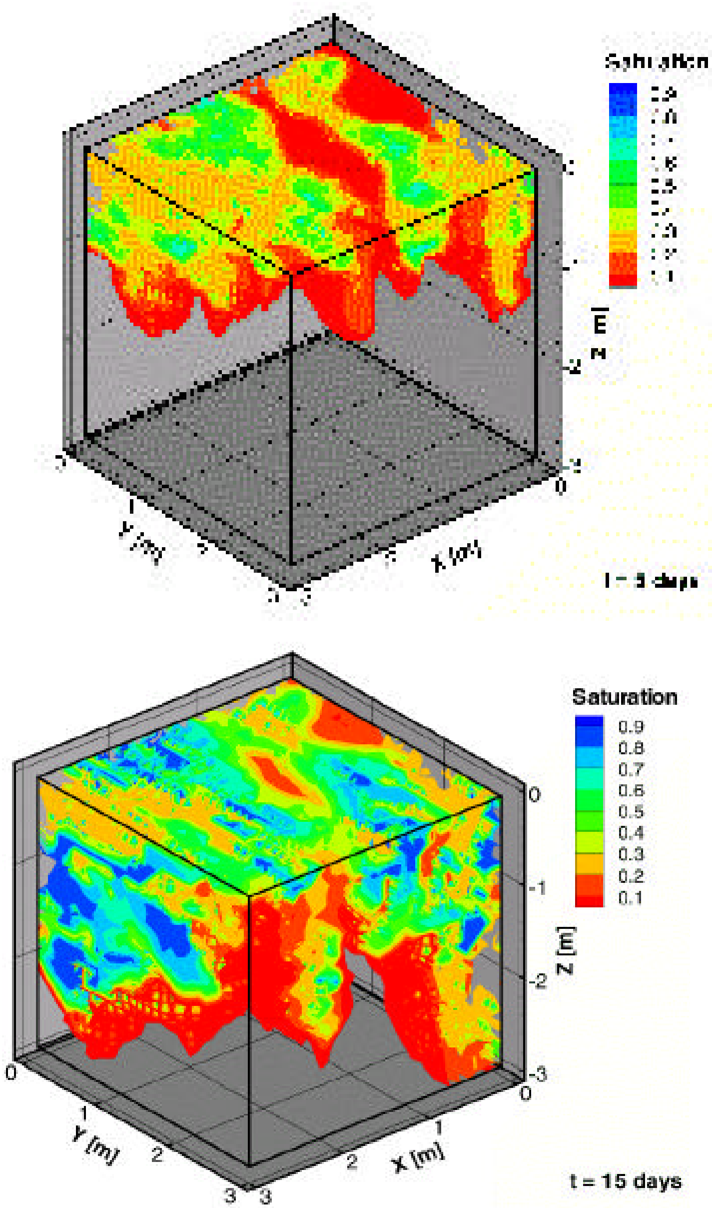
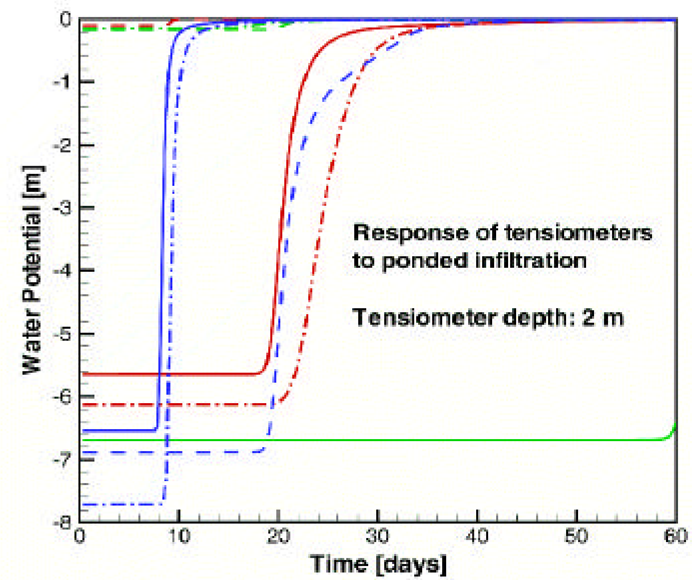
3D Water Saturation Distribution



Time variation of water potential at a 2 m depth to ponded infiltration



Modeling by S. Finsterle

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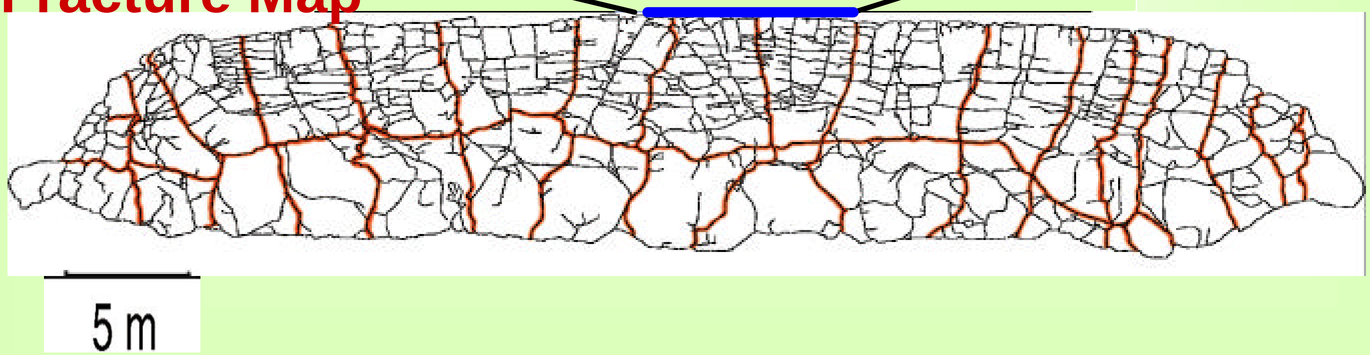
Photograph of the Infiltration Pond 7 x 8 m at Box Canyon Site, Idaho

Fracture Map



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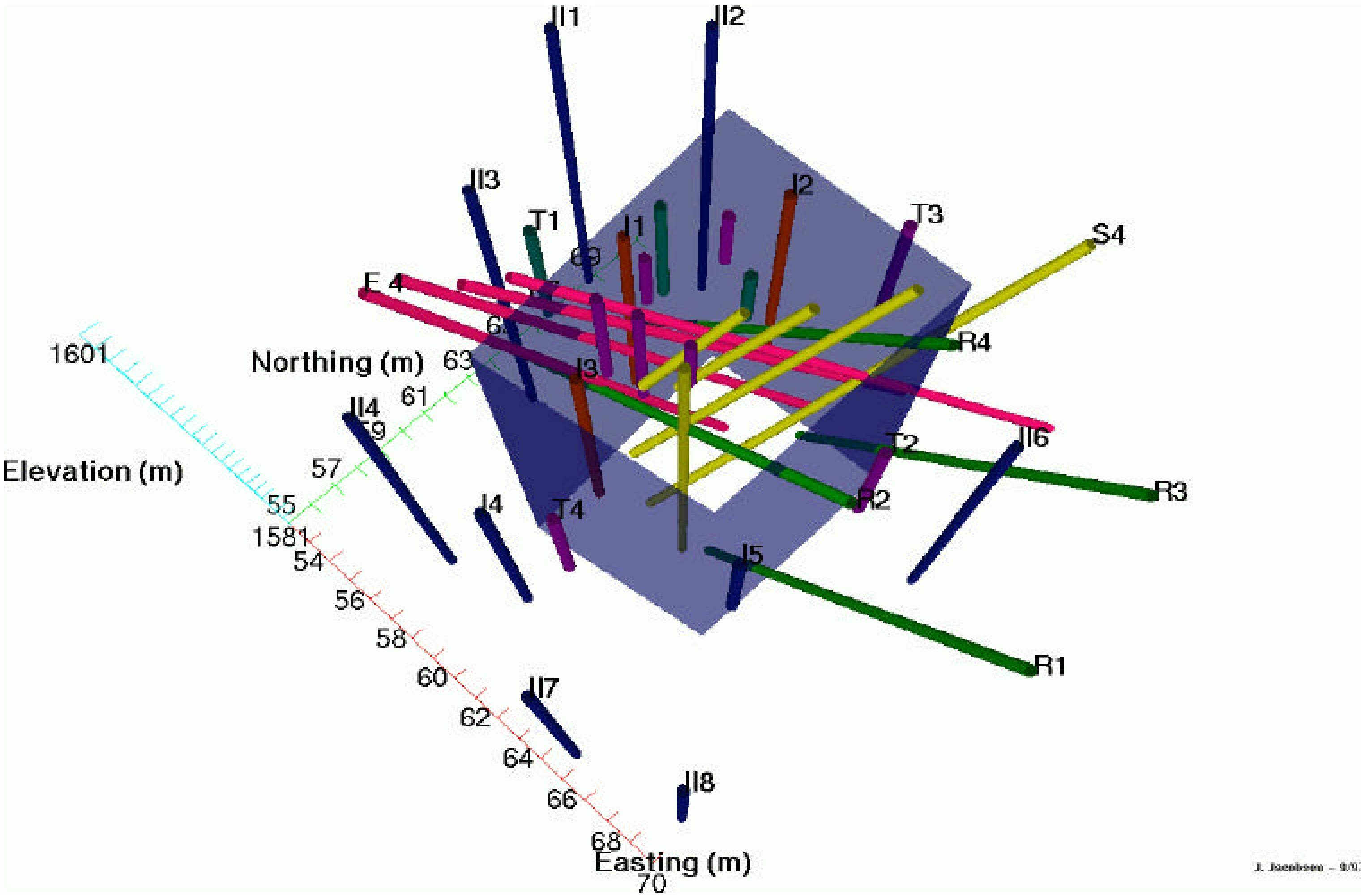
B. Faybishenko et al., Conceptual model of the geometry and physics of water flow in a fractured basalt vadose zone: Box Canyon site, Idaho, LBNL Report 42925, 1999.

Perspective View of Well Locations at Box Canyon Site



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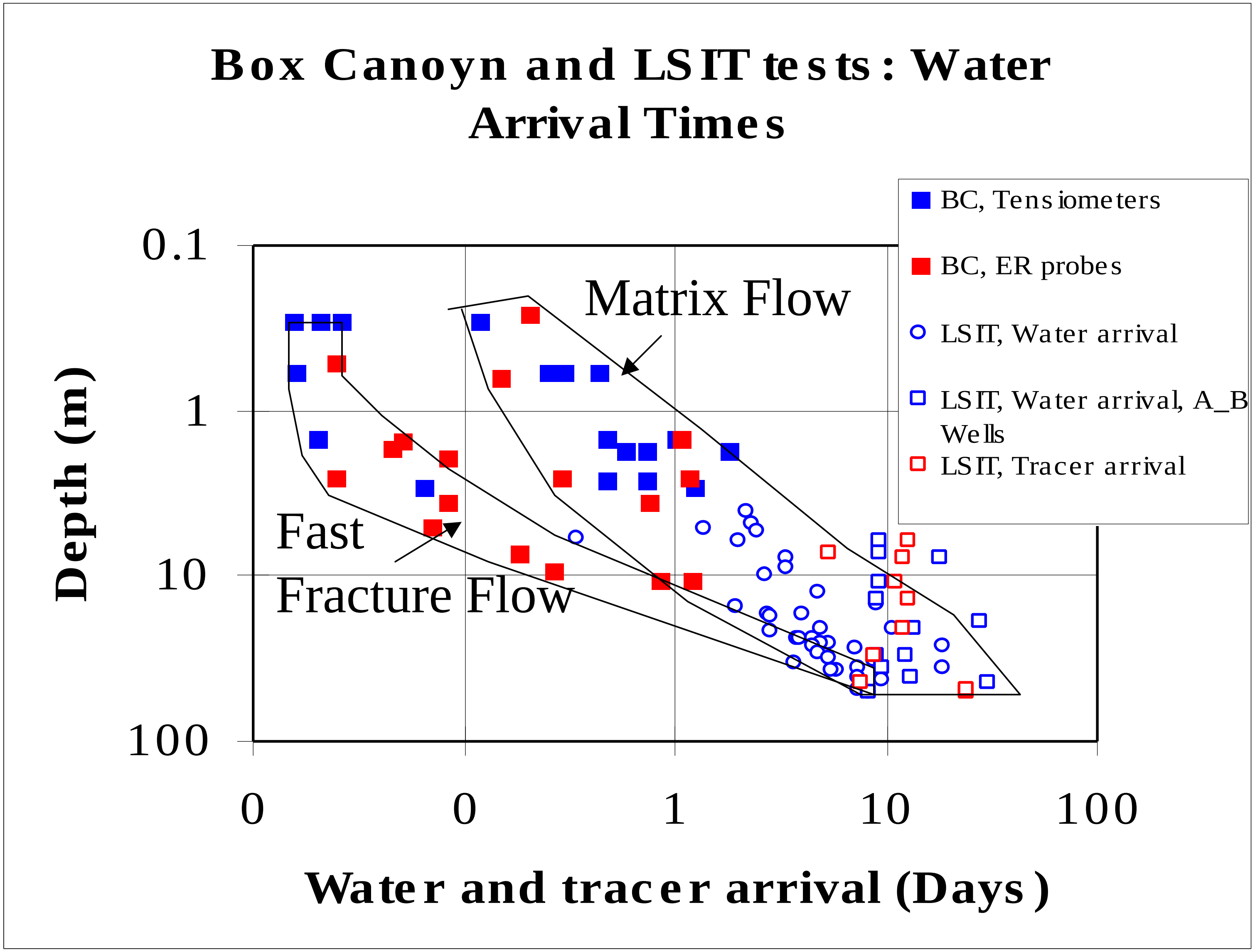

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